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Tensions of the Endless Frontier: Geostrategic Competition and the Lives of Scientists

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Abstract

Science and technology policy in both China and the United States go through a political process to passage influenced by larger diplomatic, economic, and societal goals. Often lost in these discussions are the scientists as individuals whose lives and careers are buffeted by forces beyond their control. This paper examines three case studies of Chinese scientists in the period from the mid-1940s to the 1950s, when many elite Chinese scientists made the fateful decision to remain in China, go with the Nationalist government to Taiwan, or go into exile abroad, including to the United States. These decisions reflected their personal circumstances, political affiliations, as well as the contingencies of a chaotic period of civil war. Scientific internationalism in the twentieth century helped to establish American dominance in the sciences and contributed to the success of the Manhattan Project. The three elite Chinese scientists discussed in this paper were part of the wave of foreign scientists pivotal to the development of both American and Chinese science in the twentieth century. This history provides key insights about the effect of US policy on individual scientists and lessons for the crafting of new legislation on science and technology.

Policy Implications and Key Takeaways

- The history of how American science became dominant in the twentieth century and insights from the new field of science of science both point to the importance of formal and informal social networks in the production of science.

- American science and technology policy should reward excellence on the principle that talent attracts talent and increase funding to support the educational and research infrastructure that is the basis of American dominance in the sciences. Examples of positive policies include the funding allocated in the CHIPS and Science Act for investment in hubs of excellence.

- On the other hand, policies to limit international collaboration and the pipeline of students from China could backfire by damaging international networks of science built up from the early twentieth century. Efforts to root out espionage by targeting people from particular countries of origin were not effective for the Manhattan Project—the biggest leak to the Soviet Union came from a British national. More recently, the China Initiative failed to produce concrete results other than raise alarm about civil rights infractions against scientists of Chinese origin.

Introduction

At a time of growing geopolitical tensions, it is more important than ever to restore humanity and agency to a central protagonist of these policy debates on science and technology, the scientist, and to see them not as chess pieces in a struggle between superpowers, but as individuals navigating turbulent times and making life-altering decisions based on a complex set of factors. This paper focuses on the period from 1945–1955, when many elite Chinese scientists made the fateful decision to remain in China, go with the Nationalist government to Taiwan, or to remain abroad, including in the United States. These decisions reflected their personal circumstances, political affiliations, as well as the contingencies of a chaotic period of civil war. Their histories carry important lessons for policymakers about the internationalization of science and the key factors in attracting talent. The paper focuses on three specific case studies of Chinese scientists trained in the United States in the 1940s against the backdrop of the longer history of Sino-US engagement in the sciences: the meteorologist Zhu Kezhen (Co-ching Chu 1890–1974), the aerospace engineer Qian Xuesen (1911–2009), and physicist Chien-Shiung Wu (1912–1997).

None of the three scientists, Zhu Kezhen, Qian Xuesen, or Chien-Siung Wu, were particularly politically oriented at the time of their life-changing decisions in the late 1940s and early 1950s. The most senior of the three, Zhu Kezhen, was already the president of Zhejiang University by the time of the Communist victory. Dismayed by the widespread corruption of the Chiang regime, Zhu made the decision to stay on the mainland rather than accept Chiang Kaishek's invitation to flee to Taiwan. Qian Xuesen had received tenure at Caltech and had decided to stay in the United States and apply for US citizenship before Immigration and Naturalization Service (INS) brought a case against him that resulted in his deportation back to China. C.S. Wu and her husband Luke Yuan had no communist sympathies. They remained in the United States and put down personal and professional roots. Both regularly visited Taiwan and Wu personally advised Chiang Kaishek against building a nuclear program in Taiwan. In the 1970s, however, Yuan and Wu were among the earliest groups of American scientists to travel to the PRC, despite Taiwan's official disproval. As president of the American Physical Society, Wu reached out to the Chinese Academy of Sciences and did her best to bring back Chinese scientists into the international community of physicists.

The decisions these three scientists made during this period would reverberate throughout their lives. Zhu Kezhen's oldest son, Zhu Jin (1921–1961), died in a labor camp after being labeled a rightist in 1958. Zhu's aspirations for science education in China that incorporated the best aspects of a liberal arts education in the United States were thwarted by the political turmoil of the Maoist period, which saw the Chinese Academy of Sciences shut down in 1966 and many scientists suffer intense persecution.

Upon his return to China in 1955, Qian Xuesen joined an elite group of top scientists and went on to head one of the signal scientific achievements of the Maoist era, the combined nuclear, rocket, and satellite program named "Two Bombs and One Satellite." Qian was an early advocate of cybernetics to manage complex social systems in a precursor to the CCP's full endorsement of using artificial intelligence for surveillance and state control.

C. S. Wu became the first woman to lead the American Physical Society as president in 1975. The 1957 Nobel Prize in Physics was awarded to her male colleagues Tsung Dao Lee and Chen Ning Yang for their theory on beta decay and law of conservation of parity. Wu's experiments confirmed the theory, but at the time her work was unacknowledged by the Nobel committee. Only later in life did Wu receive credit for her pioneering research. Wu was posthumously honored by the U.S. Postal Service on a commemorative forever stamp in 2021.

The three scientists' lives converged and diverged at numerous points over the course of their lives. This history illustrates the difficulties of targeting individual scientists as part of national policy on science and technology. Regulations that would ensure the attractiveness of US institutions and allow them to remain as hubs in the global development of science and new technologies would be more effective than punitive measures against individuals, which may have unforeseen and lasting repercussions.

The New Cold War

In 1945, Vannevar Bush, the Director of the US Office of Scientific Research and Development during the Second World War, submitted a report to the President on the importance of government support for science. His report, "Science, the Endless Frontier," became the founding vision for the

National Science Foundation and roadmap for American post-war scientific dominance. Seventy-five years later, in 2020, Senators Chuck Schumer and Todd Young introduced the Endless Frontier Act, later renamed as the US Innovation and Competition Act, to bolster American companies and institutions against what is widely seen as growing scientific and technological challenges from China.

The renamed CHIPS (Creating Helpful Incentives to Produce Semiconductors) and Science Act of 2022 sought to ensure US leadership in technology, including the manufacturing of the most advanced computer chips necessary for new breakthroughs in artificial intelligence and supercomputing and research into semiconductor development. The legislation aimed to reverse the long-term decline in science funding since its peak during the Cold War. According to the White House, "In the mid-1960s, at the peak of the race to the moon, the federal government invested 2 percent of GDP in research and development. By 2020, that number had fallen to less than 1 percent."[1] To help maintain American dominance in science and technology and to help spread the benefits of this dominance across the country, the administration budgeted $52.7 billion for semiconductor research, development, and manufacturing.

The CHIPS and Science Act actively counters "Made in China 2025," a state-led industrial policy announced in 2015 that sought to move China forward in high-tech manufacturing through government subsidies and the mobilization of state-owned enterprises. The ten-year plan focused on developing ten high-tech industries, including electric cars, IT and telecommunications, advanced robotics and artificial intelligence. Although Chinese officials no longer publicly tout the policy, this intensive top-down directive has already shown considerable results in the rapid growth of the Chinese electric car industry, significant advances in computer chip manufacturing, and robotics.

In recent years these two competing set of policy goals have placed the United States and China on a collision course in a new Cold War race for dominance in science and technology. Rapid developments in the field of artificial intelligence provide a compelling example of how the race in science and technology is playing out. In his 2018 best seller, *AI Superpowers: China, Silicon Valley, and the New World Order*, Kai-Fu Lee, who once headed Google China, considered China to have already taken the lead in artificial intelligence, particularly in areas like facial recognition.[2] In the book, Lee took an optimistic view of the future of AI, despite acknowledging its potential to transform the labor market and devastate white-collar jobs.

Yet, Lee fails to acknowledge the dark side of AI—its uses in surveillance and policing. Such measures are not the unintended consequence of a new technology but in fact built into the Chinese Communist Party's view of social control. New technology makes possible the unprecedented control of the population.[3] Since the publication of Lee's book, the release of ChatGPT, the large language model-based chatbot developed by OpenAI on November 30, 2022 brought the advantage temporarily back to Silicon Valley. At the same time, the development in the United States of generative AI raised urgent questions about the ethical development, use, impact, and control of a range of artificial intelligence capabilities that quickly came to dominate media and political discussions.

Alongside these discussions, surveys show that, while the United States remains the top destination for AI talent, China has expanded its domestic talent pool over the last few years to meet the demands of its own growing AI industry. China produces a sizable portion of the world's top AI researchers—rising from 29 percent in 2019 to 47 percent in 2022—many of whom work in its domestic industry.[4] China now produces almost half of the world's AI talent.[5] These developments have great significance for American policy, especially as efforts to maintain US dominance in science and technology runs a growing risk of backfiring by fostering a hostile environment to top researchers.

In contrast to the focused funding of the CHIPS and Science Act in specific areas of research and manufacturing, the Department of Justice's China Initiative, launched in 2018 to counter national security threats from the People's Republic of China, was an effort intended to root out espionage with ambiguous parameters. Legal scholar Margaret Lewis has argued that the DOJ was overly broad in using "China" as the basis for the two thousand active investigations launched by the Federal Bureau of Investigation.[6]

Although framed as addressing national security risks, most cases brought by the DOJ charged academics on issues of "research integrity," including for failure to pay taxes on payments from Chinese universities. The overly broad category of payments included relatively small honoraria commonly given for academic talks or for the review of programs. Nearly 90 percent of the cases involved defendants of Chinese heritage.[7]

By the time the DOJ formally announced the end of the China Initiative in February 2022, the program resulted in a number of prosecutions that were dismissed before trial or ended in acquittal and caused an uproar from civil rights groups and Asian American advocacy groups.[8] For example, two university faculty members embroiled in these prosecutions, Franklin Tao at the University of Kansas and Anming Hu at the University of Tennessee, eventually saw their cases dismissed, and, in Tao's case, his conviction by a jury overturned. However, these resolutions only came years after they were fired by their respective academic institutions and saw their careers and personal lives derailed.

The China Initiative was seen as having drifted considerably from its original aims of addressing national security risks. Instead of uncovering espionage, these prominent cases boiled down to whether the scientists properly disclosed their relationships with Chinese institutions. Notably, none of the cases involved the transfer of cutting-edge technology in areas of highest concern to the international community, including biomedical engineering and artificial intelligence. It also noticeably chilled research by creating more onerous reporting of *all* international collaborations, effectively dampening the internationalization of science based on transnational scientific networks built in the post-World War II period.

The Three Case Studies

The three case studies of Chinese scientists from this era bear important policy implications for the internationalization of science and the importance of attracting and protecting talent because all three center around a crucial turning point in the rise of American dominance in the sciences. Starting in the early twentieth century, science became increasingly transnational, a trend which has only accelerated in today's globalized world. The United States in particular benefited immensely from international talent immigrating to its shores in the lead up to World War II. This influx of international talent contributed to the success of the Manhattan Project and American leadership in the sciences in the twentieth century.

The history of modern science in China is deeply entangled with its engagement with the United States. China's political turmoil in the early twentieth century provided opportunities for the first generation of Chinese scientists to receive training abroad. Part of the funds from the American portion of the Chinese Boxer Indemnity went towards scholarships for Chinese students to study in the United States.[9]

Among the students who received the Boxer scholarships, Zhu Kezhen went to study agriculture at the University of Illinois, while Hu Mingfu, Zhao Yuanren, Hu Shi, and Zhou Ren went to Cornell to study the sciences, including physics, mathematics, and engineering. These and other Chinese students in the United States went on to establish the Science Society of China in 1914–1915. The Science Society returned to China with many of these students in 1918 and would go on to shape the development of the science in the country until its dissolution in 1950.

During the same period in the first half of the twentieth century, growing American global influence coincided with major philanthropic organizations like the Rockefeller Foundation expanding their footprint abroad. The Rockefeller Foundation (RF) was a key non-governmental organization in the early twentieth century, helping to promote science and the social sciences around the world. Building on a strong American missionary tradition dating to the nineteenth century, China was one of the first places where the Rockefeller Foundation provided aid. In 1906, the RF funded what was widely considered to be the finest hospital and medical school in China, the Peking Union Medical College Hospital.

In the 1920s, the RF broadened the scope of its support to agricultural science and issued funding to help existing research networks in countries like India and Mexico, as well as China. In addition to funding initiatives, the RF provided scholarships for Chinese scientists to study in the United States. Through both institutional support and individual scholarships, the RF and other major American foundations advanced the cause of science. These efforts directly influenced the development of modern science in China.

In the 1930s, top Chinese students vied for coveted spots to study in the United States. The exchange continued during the difficult war years. The histories of several scientists participating in these exchanges illustrate how internationalism has been essential to the major scientific efforts of the twentieth century, even as tensions between internationalism and nationalism persisted.

Zhu Kezhen, born in 1890, belonged to the initial generation of Chinese scientists who studied abroad. Like many of his generation, Zhu first received a classical education before going abroad for training in the sciences. He later arrived in the United States on a scholarship funded by the Chinese Boxer Indemnity and initially studied agriculture at the University of Illinois before changing his disciplinary focus and going on to receive his Ph.D. in meteorology at Harvard University. The liberal arts model at Harvard left a particularly deep impression. After his return to China in 1928, Zhu was named the founding director of the Institute of Meteorology of a newly established national academy of sciences, Academia Sinica.

In 1936, Chiang Kai-shek appointed Zhu president of Zhejiang University. Zhu retained a lifelong appreciation of the American liberal arts education, particularly the model at Harvard, where professors provided mentorship not only in academics but also a moral education.[10] Upon his appointment as the president of Zhejiang University (Zhejiang Daxue or Zheda), Zhu sought to implement this model.

Larger events, however, worked against him. In 1937, Japan launched an all-out invasion of China. Zhejiang University, like Academia Sinica and a number of other elite higher education institutions based in the coastal cities, retreated to the interior. Zheda moved to Zunyi in Guizhou. In exile and enduring difficult wartime conditions, Zhu lost both his wife and one of his sons. Zhu nevertheless persevered in his leadership of the university and its student body. During the war, Zhu first encountered the British biochemist Joseph Needham, who served as the scientific representative of the British government in China. This encounter led Zhu to send to Needham boxes of rare Chinese works in the 1950s for use in writing Needham's history of Chinese science, which eventually resulted in the landmark *Science and Civilisation* series.

Japan's surrender in 1945 did not spell the end of hardships for scientists in China. In the Republican period, Zhu had frequently collaborated with geographers to write textbooks and raise awareness of the field. The Institute of Geography was founded in August 1940 in Beibei outside of Chongqing along with the rest of the relocated Academia Sinica. After the end of the war, various teams of scientists continued fieldwork even as they faced significant budget shortfalls during the period of postwar hyperinflation.[11] On June 6, 1949, the Institute completely ran out of funds to pay employees and had to disband.[12] Under these circumstances, Zhu, along with many other scientists who found it impossible to do research in these conditions, became disillusioned by Chiang Kai-Shek's Kuomintang (KMT) regime. Although Zhu was wary of the Communists, he declined Chiang's invitation to retreat with the KMT to Taiwan. Zhu hid in Shanghai to wait for the arrival of the People's Liberation Army.[13]

This contrasted with the decision of his contemporary and fellow Boxer Indemnity fellowship recipient, the philosopher Hu Shi (1891–1962). Both Hu Shi and Zhu Kezhen had initially studied agriculture upon their arrival in the United States. After his return to China, Hu was critical of both the Nationalist government and the Communist Party for their authoritarian impulses. Nevertheless, Hu served as the Republic of China's ambassador to the United States from 1938–1942 and went with the KMT regime to Taiwan, where he served as the president of Academia Sinica from 1957 to his death.

Appointed vice president Chinese Academy of Science, Zhu Kezhen continued his life-long educational mission in the 1950s. Under the People's Republic, Academia Sinica was renamed the Chinese Academy of Sciences (CAS) and top Chinese scientists like geologist Weng Wenhao were invited to return to the mainland, whatever their previous political affiliations. The considerable personnel overlap into the late 1950s also underscores similarities between the wartime research agendas of scientific institutions under the KMT and that of newly established academies in the PRC in the 1950s. The last years of the civil war had proved exceptionally damaging to the scientific infrastructure in China and further decimated the scientific community's confidence in the KMT state.

The promise of stability in the new regime quickly dissipated in escalating crackdowns. Zhu's field of operation at the Academy of Science became increasingly constrained by the political imperative of the moment. Scientists had value insofar as they were necessary to some key areas of development valued by the regime: geologists for the survey and construction of the oil industry; physicists for the nuclear program; and biologists for enhancing the country's agricultural production.

With a few exceptions, however, by the late 1950s these scientists were also seen as dispensable. As political campaigns ramped up in the late 1950s, they claimed an increasing number of scientists among their victims, including Zhu Kezhen's oldest son Zhu Jin (1921–1961) who was labeled a rightist in 1958 and died in a labor camp.[14] Weng was one of the highest-level KMT officials to return to the mainland and his repatriation represented a major coup for the new state. While Weng himself survived the Cultural Revolution, his oldest son, a petroleum engineer, was killed.

In the face of these difficulties, Zhu continued to do what he could to advocate for and practice science. As China was emerging from the Cultural Revolution, Zhu published the most well-known article of his career in 1973, "A Preliminary Study on the Climatic Fluctuations During the Last 5,000 Years in China."[15] The importance of the article can be seen in its immediate translation into English and publication in *Scientia Sinica* mere months after its appearance in Chinese. In the article, Zhu applies one of the significant advantages China possessed, the country's unmatched historical records, to argue for the historical fluctuation of climate in periodic cycles. By combining archaeology, history, and weather science, in the year before his death Zhu returned to his long-held educational aims of bringing together humanities and the sciences.

Like Zhu Kezhen nearly two decades earlier, Qian Xuesen received a Boxer Indemnity Scholarship to study in the United States. Qian arrived in the United States in 1935, initially enrolling at MIT. In the 1930s, the MIT aeronautics program focused not only on theory but also on airplane design and included among its star professors several pioneers of the aircraft industry. Qian, however, struggled with the experimental work and long hours spent testing in wind tunnels.

Following his master's thesis, Qian went to meet the Hungarian-born mathematician and physicist Theodore von Kármán at Caltech. Kármán had grown increasingly alarmed by the deteriorating political situation in Europe and in 1930 had accepted the position of the director of the Aeronautical Laboratory at Caltech. From this base, Karman built up a tight-knit group of graduate students.

In the 1930s, US institutions became the main beneficiaries of a flood of talent driven by the deteriorating political situation from Europe. Growing antisemitism in Germany and Austria forced out some of the brightest minds in Europe from professorships and research positions. Others, seeing the writing on the wall, looked elsewhere before they were forced out. In addition to Kármán, John von Neumann, Albert Einstein, and Wolfang Pauli were among the top physicists and mathematicians to decamp to the United States.

The stream of exiles turned into a flood as war spread in Europe. Several of the top European physicists and mathematicians found employment at the Institute of Advanced Study at Princeton. Others found positions at institutions across the United States. In turn, these transplants helped turn the United States into the world leader in theoretical physics.

In California, the introverted and intensely intellectual Qian found his community. In the 1930s, Caltech attracted some of the best scientists in the world. T.H. Morgan, the chair of the biology department, would go on to win a Nobel Prize for his genetic study of fruit fly chromosome. Qian Xuesen became part of a group of Chinese students, a number of whom went on to become pioneering scientists in China. The geneticists Li Ruqi and Tan Jiazhen both received research fellowships from the Rockefeller Foundation to work with Morgan's group. Both Li and Tan would return to China to be leading proponents of genetics study in China.[16]

The circle of world-class physicists then as now was quite small. J. Robert Oppenheimer had studied under Max Born at the University of Göttingen, where von Kármán had received his Ph.D. in 1908. In the 1930s, Oppenheimer joined the physics department at UC Berkeley. Oppenheimer brought to the United States the latest European developments in quantum physics and made Berkeley a hub for theoretical physics. Pauli and Kármán studied together in Germany. A coterie of Hungarians, Theodore von Kármán, John von Neumann, Leó Szilárd, Edward Teller and Eugene Wigner, were all raised in wealthy, intellectual Jewish families, and reunited in the United States in the 1930s to change the course of science and world history.

Equally small was the coterie of Chinese students in the United States. Qian Xuesen, by then president of the Chinese Students Association at Caltech, filmed scientists Wu Chien-Shiung and Luke Yuan's wedding on Sunday May 30, 1942, in the home of Luke's advisor Robert Milikan, the Nobel Prize winner and president of Caltech at the time.[17] Hu Shi had been Wu's favorite teacher in China, a mentor later in life, and she was visiting Academia Sinica in Taiwan in 1962 when Hu suddenly took ill and passed away. The California Chinese students group moved in the same circles of Von Kármán, Oppenheimer, and Lawrence.

The politically liberal intellectual hothouse environment in California made it a hub for top scientists, as well as for the leftist movement in the United States. Events overseas, most notably the Spanish Civil War, fueled the recruitment efforts of the American Communist Party. From this rich pool of talent, a number went to work for the Manhattan Project to join the effort against Nazism. Oppenheimer was tapped to head the Manhattan Project despite his close relationships with a number of Communist Party members, including his former lover Jean Tatlock and his brother Frank. The political undercurrents would also drag Qian under in the 1950s.

Qian was one of Kármán's most talented students, by the 1950s a tenured professor at Caltech and moreover, a participant in the Manhattan Project during the war and core member of the pioneering rocketry program. For these wartime efforts, Qian had received the clearance for top secret military research. But part of what led to Qian's deportation after two years of house arrest was the tension between US immigration law and national security concerns. Because of his participation in classified research, the US government had initially deemed Qian too dangerous to send back to China.

However, the FBI and the INS apparently failed to communicate their conflicting agendas, prevent Qian from leaking sensitive knowledge for the former and to deport Qian to China for his alleged communist affiliations for the latter. On November 15, 1950, the INS held a deportation hearing in downtown Los Angeles. At the hearing, the INS produced no conclusive evidence of Qian's alleged Communist ties. Qian admitted that he may have been present at social gatherings in the late 1930s which might have been Communist meetings.[18] He was, however, never on any Party membership rosters.

On April 26, 1951, the INS ruled that Qian was "an alien who was a member of the Communist Party of the United States" and subject to deportation. For three years from 1951 to 1954, Qian was in a state of limbo while he fought the deportation order. He was not allowed to return to his classified work and forbidden from travel outside of Los Angeles, which meant that he could no longer take part in most academic conferences.

In the early 1950s, paranoia pervaded government agencies. The American monopoly on nuclear weapons ended in September 1949 when the Soviet

Union exploded its first atomic bomb. Suspicions of espionage were confirmed when the British announced that Dr. Klaus Fuchs, a scientist who worked at Los Alamos, had given the Soviets atomic secrets to develop their bomb. Shortly thereafter, Communist forces prevailed in the Chinese Civil War. Government agencies went into overdrive investigating possible Communist or Soviet agents. The charges that Qian faced were based on flimsy circumstantial evidence at best, and the conflicting agendas of INS and FBI placed Qian in an impossible situation.

The Korean War intervened to both save Taiwan from imminent communist invasion and to result in Qian's return to China. In 1955, the United States recommitted to defending the Republic of China in Taiwan against Communist invasion. By then, about one hundred Chinese students remained in limbo like Qian Xuesen. In a memo to President Eisenhower, Secretary of State Dulles proposed the exchange of these students for American POWs held in China. In negotiations between US Ambassador Johnson and Ambassador Wang from the PRC, Wang mentioned Qian by name.[19] In August of 1955, Qian was finally allowed to leave.

Welcomed back to China as a returning hero, Qian quickly joined an elite group of scientists working on China's nuclear and satellite program. But the story does not end there. In a 1957 *People's Daily* article, Qian Xuesen called on the Chinese Academy of Social Sciences to take the concept of social management seriously as a way of solving complex social issues. The following year, in December 1958, Qian joined the Communist Party. In the following years Qian became an increasingly ideological hard-liner in his support of the party. Some critics viewed an article Qian wrote in 1958, in which he proclaimed the possibility of increasing agricultural yield by a factor twenty, as one of the inspirations for Mao's disastrous policies during the Great Leap Forward.[20]

By the 1970s and throughout the 1980s, using technology for social management gained prominence in the upper levels of the CCP, even as Qian himself was increasingly marginalized because of his interest in extrasensory perception (ESP) and other unconventional areas of study. Qian only returned to national eminence after the student protests in 1989, when he openly embraced the hardline, denouncing dissidents like the physicist Fang Lizhi as "scum of the nation" and the student protestors as "ruffians."[21]

As a result of this stance, in his last years Qian became one of the best known and celebrated scientists in China. Posthumously, the Qian Xuesen Library on the Jiaotong University campus in Shanghai has been designated a Red tourism site. An exhibit in the newly opened Shanghai Astronomy described Qian's repatriation in 1955 as a "voluntary" return done out of love for his homeland. A June 2024 CCTV program featured an AI generated Qian Xuesen hologram that exhorted Chinese people to reach for the stars in support of the space program. The real Qian has literally disappeared behind a CCP approved AI figurehead.

Chien-Shiung (C.S.) Wu left China in August 1936. Her mother, father and uncle saw her off on the docks by the Bund for the passage across the Pacific. It would be the last time she saw her parents and 37 years before she returned to China in 1973.[22] Wu stopped in San Francisco on her way to the University of Michigan, her original destination. She never made it past UC Berkeley, discovering, as did Qian Xuesen, that the California schools had captured an extraordinary group of top scientists in the 1930s.

On a tour of the Berkeley campus, led by her future husband Luke Yuan, who had arrived some weeks earlier, Wu was impressed by the Radiation Laboratory built by Ernest Lawrence, which featured a 37-inch cyclotron, the first in the world. Lawrence envisioned the cyclotron to conduct nuclear experiments by accelerating charged particles to bombard nuclei.[23] Working closely with Lawrence was another young and brilliant physicist named J. Robert Oppenheimer. Wu decided to stay at Berkeley for her graduate studies. Under the tutelage of Emilio Segre, Wu became a top-notch experimental physicist during these formative years of graduate training. She obtained her Ph.D. in 1940. Two years later, she married Luke Yuan at a ceremony in the garden of Robert Millikan, then the President of Caltech. Their life moved to the East Coast when Yuan landed a job at RCA in Princeton.

The newly-weds' life together proceeded as the situation in China steadily deteriorated. Shortly after Wu first arrived in the United States in 1936, China entered a desperate war for survival against the Japanese invasion. After they moved to the East Coast, Wu contributed to the experimental work needed for the Manhattan Project, now overseen by one of her former mentors at Berkeley, J. Robert Oppenheimer. World War II in the Pacific theater ended with Japanese surrender in August 1945 after the US dropped two atomic bombs on Hiroshima and Nagasaki.

Japanese defeat did not mean the end of war in China. Instead, the civil war in China ramped up between Communist and Nationalist forces, which had been in an uneasy united front during the war against the common Japanese enemy. Wu and Yuan's only child, a son, was born in Princeton in 1947. Their plans to return to China were pushed back repeatedly as the KMT steadily ceded ground.

Wu's father had been an educator and progressive in his younger years, but he was not a fan of the communists. He urged the couple not to return.[24] In 1949, Luke joined the Brookhaven National Laboratory on Long Island. Wu got a job at Columbia University. Chiang Kai-Shek retreated with some of his forces to Taiwan. That October, Mao Zedong proclaimed the establishment of the People's Republic of China from atop Tiananmen Square.

By the time US-China relations thawed and contact was re-established between the two countries, Wu was at the top of her profession. In 1954, Wu provided the experimental proof for the non-conservation of parity. The idea had been proposed by T.D. Lee and C.N. Yang, both of whom were awarded the 1957 Nobel Prize in Physics. Many felt that Wu should have received the Nobel Prize as well for her contribution. Recognition for her work would arrive late, in the 1970s, when Wu received the highest accolades from her profession and from the US government for her pioneering contributions to science.

In May 1972, Wu declined a post as Commissioner of the US Atomic Commission, citing as her reason the need to focus on her research.[25] In 1975, she became the first female president of the American Physical Society. In 1978, she was awarded the inaugural Wolf Prize in Physics. She returned to the People's Republic of China for the first time since 1936 on an extended trip from September to November in 1973.

From her days at Berkeley, Wu was part of an elite network of top physicists from around the world. A number of her colleagues were quite intrigued by developments in China after 1949, and, when the country reopened to foreign visitors, rushed to sign up for delegations visiting China. The Danish scientist Bernhard Deutsch wrote to Wu that, "my Chinese friends have been overwhelmed by requests from American scientists for visiting permission."[26] As a Dane, Deutsch had not been under the same constraints as the American scientists, whose government did not officially recognize the PRC as the legitimate government of China.

Fellow scientist Louis Alvarez's mother had been born in China to missionary parents. He himself long advocated for scientific internationalism and in 1962, had contacted a Canadian colleague about an invitation to China.[27] Once relations between the two countries thawed, Alvarez participated in a 1973 trip to China. In a letter to Wu dated September 10, 1973, he described his experience visiting Chinese scientific institutions. While finding Chinese scientists friendly and deeply interested in scientific developments overseas, Alvaraz was unimpressed by the facilities he visited, noting that, "But I would not say that the physics I saw in China was even mildly interesting, by western standards."[28]

As the first woman to be president of the American Physical Society, Wu broke gender barriers. She also promoted a vision of internationalism for science. When she became president of APS a decade later, Wu made sure to continue the overtures from American scientific community to the PRC, sending the list of invited papers to the Chinese delegation and issuing an invitation to the Chinese Academy of Sciences to attend the APS conference in Denver. A group of Chinese solid-state physicists attended the APS meeting.[29] The group later wrote a letter of thanks upon their return to China. Wu was in contact with the Committee on Scholarly Communication with the People's Republic of China and with Chinese student group across the country, many of whom issued invitations to her as an inspirational figure among Chinese American scientists.[30] Along with Lee and Yang, Wu would regularly release public statements protesting racist incidents against Chinese Americans in the 1970s and 1980s and actively participated in the New York Chinese community.

Is American Science in Decline?

In recent years, China's rise as a scientific power has renewed interest in longstanding debates about the key factors in scientific prominence. Historians and practicing scientists have long mulled over the factors leading to innovation and national scientific prominence. In 1830, Charles Babbage published *Reflections on the Decline of Science in England* on the common perception that English science was in decline, particularly compared to French advances. By the 1860s, the French, including critical reports by Claude Bernard (1867), Louis Pasteur (1868), and Adolphe Wurtz (1870), compared themselves unfavorably against the Germans.

This declinist literature was often written by practitioners of scientific disciplines to critique the institutional constraints, lack of funding, and other flaws of science in their own countries. Historian of Science Mary Jo Nye has argued that quantitative assessments do not bear out any actual decline in France in the late nineteenth and early twentieth centuries.[31] David Edgerton has similarly pointed to discrepancies between quantitative measures and narratives of decline in Britain. Edgerton traces part of the problem to primary sources and the uncritical reliance on testimony from scientists, engineers, and industrialists, who paradoxically voiced the loudest complaints "in periods of exceptionally rapid growth in funding."[32]

This discrepancy between perception and data raises questions about how and what kind of quantitative data should be used in measuring national scientific achievements and the objectiveness of such data. Should researchers use numbers of publications; patents filed; or new discoveries made? What should count as a significant discovery?

Moreover, there is clearly a lag time between expressions of discontent by members of the scientific community and when the actual decline occurs. Nye and Zuckerman, among others, have both suggested that awards such as the Nobel Prize might be better indicators of scientific prominence than the total number of publications.[33] Since research that results in prestigious prizes often takes place years if not decades before the award itself, and moreover may be the result of collaborative work from multiple researchers in different fields and from different countries, this measure also has significant flaws.

As science and technology studies became a distinct discipline, historians and sociologists of science began to apply quantitative data to the study of scientific achievements. The pioneer of the field, Derek de Solla Price, for example, applied humanistic techniques to the study of how science developed.[34] At the same time, Price also used quantitative methods to study the development of science, arguing already in 1951 that "the number of scientific papers published each year may be taken as a rough indication of the activity displayed in any general or specialized field of research."[35] The number of scientific publications by country has since become the most common statistic used in the measure of scientific prominence. However, this statistic does not reflect research collaborations and connections between different countries.

From the quantitative side, sociologists of science have approached the question of scientific knowledge and community construction by examining census and other datasets about the numbers of science and technology degrees, pay and status of scientists, and levels of state support. This has been aided by NSF publications of *Science and Engineering Indicators*.[36] In a 2012 work, *Is American Science in Decline,* sociologists Yu Xie and Alexandra A. Killewald analyzed census and NSF data to answer a qualified no.[37] Part of the issue is the measure of scientific achievement. In terms of the number of science and engineering degrees and publications, China has already overtaken the United States. But at the elite levels of science, the United States maintains an edge.

In the years since Xie and Killewald's 2012 book, some of the trends they examined have further accelerated. Xie has since used Chinese data on the numbers of science and technology degrees to the total labor force and other statistics to examine the causes of China's increasing contribution to science and technology.[38] These data analyses, however, do not account for the increasing mobility of scientists and the larger historical trajectory of Chinese science. Since the 1980s, millions of Chinese students have headed overseas for advanced degrees. Many of the country's top scientists received their Ph.D. training abroad and returned to China at various stages of their career. Research by historians like Zuoyue Wang has shown the importance of overseas Chinese scientists in restarting the country's research agenda in the post-Mao period.[39]

Finally, since the heyday of Big Science in the postwar period, US government support for basic research has significantly declined as an overall percentage of research and development, replaced by transnational corporations with their own inhouse R&D.[40] The privatization of science further dispersed scientific research, with large companies in the pharmaceutical industry, for example, outsourcing research to international subsidiaries.

Even before this trend became especially pronounced in countries around the world, science studies often struggled with how to classify figures like the American Jesse Beams (1898–1977), who, over decades as the chair of the

University of Virginia physics department also founded two private companies, served as consultants for other firms, and participated in the Manhattan Project.[41] Today, computer scientists and top tech companies like Google and Microsoft occupy this gray zone between state and private enterprise.

The displacement of leading scientists by the two World Wars in the twentieth century, with the United States as the prime beneficiary began a trend that has accelerated in recent years. During the last decade, the science of science has developed into an emerging field of studies that focuses on a big data approach to questions about impacts and collaborations in science.[42] Studies in this field have examined scientists' growing global mobility. A global survey of 17,000 researchers in four fields (chemistry, biology, Earth and environmental sciences, and materials) in 16 countries showed a high degree of international mobility among scientists, with the United States as the top destination.[43]

Yet, the numbers do not fully reveal the entangled nature of these transnational networks, particularly in specific disciplines and between elite institutions. The lives and careers of Zhu Kezhen, Qian Xuesen, and C.S. Wu illustrate the multiple points of intersection and connections among elite scientists. All three made significant contributions to science and society in ways that defy easy categorization strictly according to national boundaries. Their training at institutions in the US reflect the appeal of American science as a safe haven during a time of considerable international turmoil.

Conclusion

The lives of the three case study scientists can only be understood in the larger context of scientific internationalism in the twentieth century and the outside forces that brought the three of them to the United States, as well as top scientific talent from Europe to American institutions in the 1930s and 1940s. These three scientists each reached the pinnacle of their professions. All three were deeply embedded in an international network of scientists in their respective fields. In the late 1940s and early 1950s, a period of exceptional turmoil in China, each had made life-changing decisions based on incomplete information subject to larger historical forces outside of their control. Their political views and affiliations and career trajectory up to the divergence of their paths played only minor roles in these complex calculations.

From their stories, it becomes clear that targeting individuals over their loyalty proved ineffective and counterproductive in the 1950s. Similarly, emerging data on contemporary international networks of science, warns against efforts to restrict Chinese students, particularly in science and engineering fields, at American universities. Most of the recent cases brought by the China Initiative foundered from the lack of evidence and managed only to ruin people's lives. Policies that limit international collaboration and the student pipeline from China could backfire by damaging international networks of science built up from the early twentieth century. Such policies could also make the United States a less desirable place for scientists and students alike, and thus, a less effective place for research and science.

The United States emerged as a global leader in science technology in the twentieth century, replacing Germany as a hub for top talent in physics, partly because it was seen as a haven from racial persecution in Europe. The ideal of scientific freedom may well have been a creation of American mythmaking—scientists lived and worked in the context of their times and operated under the cultural and political constraints of their countries—but for a time, this idea created the conditions for science to thrive in the United States and to make the country a hub for cutting edge research.[44] The internationalization of science in turn made it a key channel of diplomacy during the Cold War, a trend that continues today. Targeting the conduits of such exchange, the scientists, risks undermining the foundations of science.

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